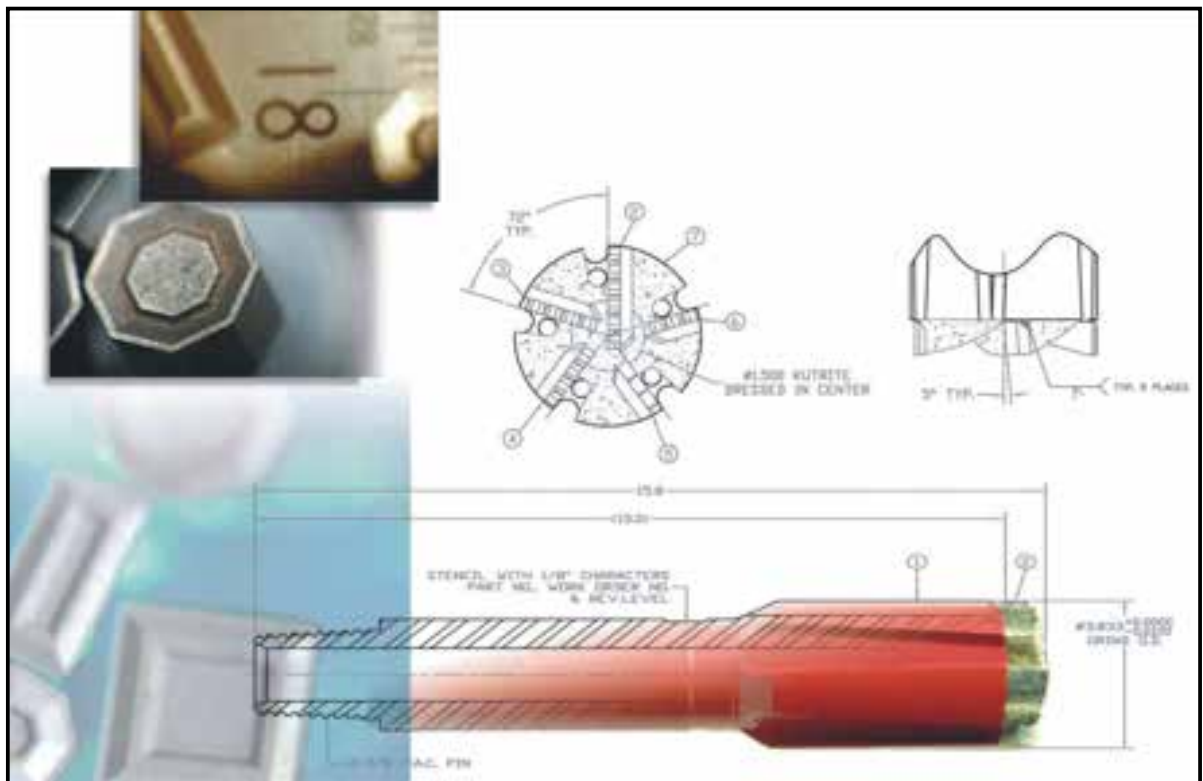




Guidelines for Effective Milling

MillSmart™ Technology

Featuring CustomCut™ inserts—because each job is different



Drilling



Evaluation



Completion



Production



Intervention

Fishing Services

- Fishing tools

- Casing scrapers
- Mills

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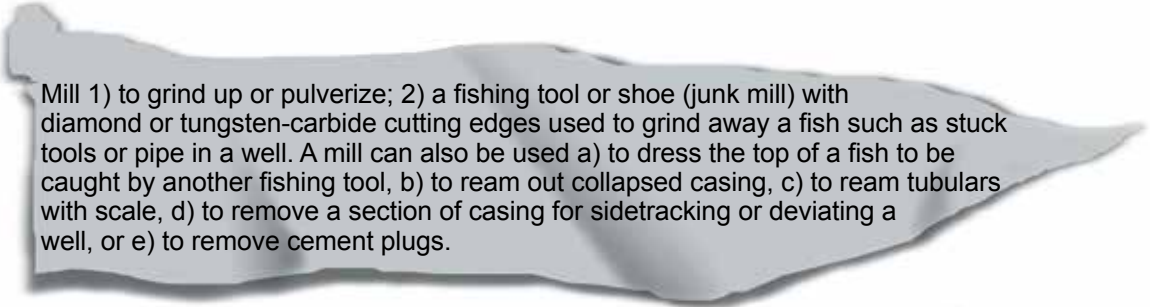
Introduction

Al-Shaheen Well Services provides in Qatar the same fishing services that Weatherford International Ltd provides worldwide. Our highly experienced teams of fishing tool supervisors and operators are ready to meet any challenge, and we offer the world's most advanced and comprehensive line of fishing tools for any application:

- Junk mills for removing stuck pipe, tubing, bridge plugs, packers, and cement or other debris obstructing the wellbore
- Pilot mills for effectively milling casing, liners, rotary shoes, wash pipe, or large-ID tubing
- Taper mills for reaming out restrictions, collapsed casing, and liner sections
- Watermelon/string mills for milling collapsed areas in casing and liners, eliminating key seats and doglegs, and extending whipstock windows
- Section mills for cutting sections of casing or for setting whipstocks
- Rotary shoes for freeing tubulars that have become sand stuck, mud stuck, or mechanically stuck and for milling over packers, retainers, and bridge plugs

Al-Shaheen offers these and many other milling tools plus everything from jars to boot baskets, cutters to overshots, casing scrapers to underreamers, and knuckle joints to fishing magnets. And we serve your needs quickly with a wide array of fishing tools in stock and ready to go.

Milling success depends on good mill design and efficient job execution. This handbook, concerned with job execution, represents a distillation of valuable best practices, gleaned from decades of operational experience, to help improve the efficiency and outcomes of your milling operations. We hope you will find this book to be a valuable reference.



Mill 1) to grind up or pulverize; 2) a fishing tool or shoe (junk mill) with diamond or tungsten-carbide cutting edges used to grind away a fish such as stuck tools or pipe in a well. A mill can also be used a) to dress the top of a fish to be caught by another fishing tool, b) to ream out collapsed casing, c) to ream tubulars with scale, d) to remove a section of casing for sidetracking or deviating a well, or e) to remove cement plugs.

-- Excerpt from the Dictionary of Petroleum Exploration, Drilling & Production
Norman J. Hyne, PH.D.



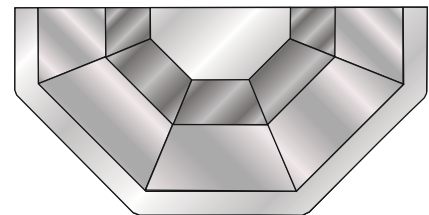
Introduction

MillSmartSM Technology—An Engineered Approach to Milling

While the definition of the word is quite straightforward, there's much more to successful milling than people might realize. To plan an effective milling operation, a number of things must be considered. MillSmart milling technology is an engineered approach to milling that encompasses a wide range of proven products, services and technical resources, developed and refined by Weatherford, the world's largest and most experienced provider of milling and fishing services. MillSmart technology is based on a tremendous amount of milling data—gathered by Weatherford's worldwide Performance Tracking System and used to create best practices for almost every imaginable application.

MillSmart customized hydraulic modeling software for job planning gives you the most realistic preview possible of a proposed milling operation. Their suite of HydraPro[™], HydraForce[™], Hydra-Cut[™] and HydraBoost[™] software focuses on extended-reach, deepwater, horizontal, high-angle, high-temperature/high-pressure and other high-profile well designs for which pre-job planning is crucial.

CustomCut milling- or cutting-grade inserts are available in various configurations and geometries. Advanced mill engineering and certified welders ensure a consistent and durable cutting structure on every mill and rotary shoe we produce.



CustomCut inserts feature a proprietary negative rake and chip breaker design that effectively breaks up the cuttings. This provides smaller, thinner and lighter cuttings that are quickly and easily circulated and flowed to the surface for better hole cleaning efficiency and faster penetration rates.

MillSmart technology and CustomCut carbide inserts are a major leap forward in performance, using materials and designs that contribute to a complete system process approach. Focused research and engineering efforts and extensive field experience and case studies have generated a family of special-application carbide milling products—the CustomCut 100, 200 and 300 series.

CustomCut inserts can be teamed with the revolutionary new PowerStroke[™] milling system, which features a unique reciprocating, highly flexible broach milling design that reduces tool stress and maintains communication between shifted sections to prevent sidetracking. In its first field trial, the PowerStroke system remediated two severe doglegs in one well in a single trip.

Custom Mills

Milling and pipe cutting are required in a variety of situations, including offshore well abandonment, loose junk retrieval, section milling, fish-top cleanup, washovers, and milling of major obstructions. Over the years Weatherford engineers have designed and manufactured thousands of mills, both standard and custom. Need a custom mill for a unique situation? Weatherford operations and engineering personnel have probably already addressed something very similar. They can design and manufacture a custom tool to your specifications.

General Operational Recommendations

Each type of milling operation presents its own set of challenges, for which we provide recommendations in the following pages; however, certain recommendations for optimizing milling rates and cutting returns apply to all kinds of milling situations.

Optimizing Milling Rates

Milling rates are affected by the type and stability of the fish (cemented or not); weight on the mill; running speed of the mill; carbide dressing of the mill; stiffness and vibration of the drill collars; and hardness of the fish or cement. Table 1 provides guidelines for optimizing milling rates in various situations.

Table 1—Typical Challenges Remedied by Adjustment of Milling Rate

Challenge	Recommendation
Cemented casing	Increase mill speed and weight on the mill to improve the rate of penetration (ROP).
Uncemented casing	Mill at slower speeds, with less weight on the mill.
Severely corroded casing	Increase speed and decrease weight on the mill to prevent tearing or splintering of the casing.
Rubber in the hole	When milling rates decrease, decrease the pump strokes, or turn off the pumps. Pick up the work string, and spud the mill to help engage and break up the rubber.
Unstable mill	Run a stabilizer above the mill, if possible. The OD of the stabilizer should not exceed the dressed OD of the mill.
Bouncing or rough operation	Decrease the speed and weight on the mill until the milling operation becomes smoother. After an hour, slowly increase the speed and weight. If the ROP is acceptable, continue at the same speed and weight; if not, increase the speed and weight until an acceptable ROP is achieved. If necessary, repeat the procedure until milling can resume. A shock sub can be run just above the mill to reduce vibration.
Older-model liner hangers, centralizers, and scratchers	Most liner hangers mill easily, but some old types have slips and rotating parts. When these types are encountered, pick up the work string, and spud the mill frequently to reposition and break up the hanger parts for effective milling. In milling centralizers and scratchers, use the largest-OD mill that can be run into the wellbore to ensure the best



General Operational Recommendations

Rotary Speeds

Experienced operators often intuitively determine the rotary speed required for effective milling rates. Small mills—up to 8-1/2 in. (216 mm) in diameter—can sometimes be run up to 150 RPM but usually are kept to about 100 RPM to prevent the drillpipe from whipping around. If run at a high speed, a mill can stick momentarily, causing the pipe to twist until the mill releases it. The string then violently untwists, often breaking tool joint connections or twisting off the pipe. Therefore, for small mills, the drillstring and hole conditions limit rotary speed. Run ample drill-collar weight to provide the inertia required to keep the work string at a constant rotary speed.

A high surface-feet-per-minute (SFPM) speed can burn or damage tungsten carbide mills. Crushed tungsten carbide cuts steel best at 150 to 200 SFPM (45.7 to 61.0 surface-meters-per-minute [SMPM]). CustomCut™ tungsten carbide inserts cut steel best at 150 to 350 SFPM (45.7 to 106.7 SMPM). Use the formula and example in Table 2 to determine the minimum and maximum recommended speeds.

Weights for Mills and Rotary Shoes

Excessive weight on the mill and rotary shoe can damage the tungsten carbide that mills steel. Crushed tungsten carbide cuts steel best at 100 to 500 PSI (689 to 3,447 kPa). Tungsten carbide inserts cut steel best at 150 to 500 PSI (1,034 to 3,447 kPa).

Use the formulas and examples in Tables 3 and 4 to determine the recommended minimum and maximum weights on the mill and on the rotary shoe, respectively

Table 2—Formula for SFPM

Formula	Example for an 8 5/8-in. OD Junk Mill at 110 RPM
$OD \times RPM \times 0.262 = SFPM$	$8.625 \times 110 \text{ RPM} \times 0.262 = 249 \text{ SFPM}$

Table 3—Formulas for Determining Weight on the Mill

Formulas	Examples for an 8 5/8-in. OD Junk Mill
$OD^2 \times 0.7854 \times 100$ (minimum crushed) = Recommended weight on mill	$8.625^2 \times 0.7854 \times 100$ (minimum crushed) = 5,842 lb on mill
$OD^2 \times 0.7854 \times 500$ (maximum crushed) = Recommended weight on mill	$8.625^2 \times 0.7854 \times 500$ (maximum crushed) = 29,213 lb on mill
$OD^2 \times 0.7854 \times 150$ (minimum insert) = Recommended weight on mill	$8.625^2 \times 0.7854 \times 150$ (minimum insert) = 8,764 lb on mill
$OD^2 \times 0.7854 \times 500$ (maximum insert) = Recommended weight on mill	$8.625^2 \times 0.7854 \times 500$ (maximum insert) = 29,213 lb on mill

Table 4—Formulas for Determining Weight on the Rotary Shoe

Formulas	Examples for an 8 5/8-in. OD x 7 1/4-in. ID Rotary Shoe
$(OD^2 - ID^2) \times 0.7854 \times 100$ (minimum crushed) = Recommended weight on rotary shoe	$(8.625^2 - 7.250^2) \times 0.7854 \times 100$ (minimum crushed) = 1,714 lb on rotary shoe
$(OD^2 - ID^2) \times 0.7854 \times 500$ (maximum crushed) = Recommended weight on rotary shoe	$(8.625^2 - 7.250^2) \times 0.7854 \times 500$ (maximum crushed) = 8,522 lb on rotary shoe
$(OD^2 - ID^2) \times 0.7854 \times 150$ (minimum insert) = Recommended weight on rotary shoe	$(8.625^2 - 7.250^2) \times 0.7854 \times 150$ (minimum insert) = 2,571 lb on rotary shoe
$(OD^2 - ID^2) \times 0.7854 \times 500$ (maximum insert) = Recommended weight on rotary shoe	$(8.625^2 - 7.250^2) \times 0.7854 \times 500$ (maximum insert) = 8,572 lb on rotary shoe

General Operational Recommendations

Optimizing Cutting Returns

The ideal cutting is usually 3/32 to 1/4 in. (2.38 to 6.35 mm) thick and 2 to 4 in. (50.80 to 101.60 mm) long.

If cuttings are thin or hair-like and ROPs are low, increase the weight on the tool.

If fish-scale cuttings are returned during pilot or section milling (common when milling H-40, J-55, and K-55 pipe), improve ROPs by decreasing the weight and increasing the rotary table speed. When milling N-80 or P-110 pipe, finer cutting returns can be expected.

The following are guidelines for the optimal use of drilling mud to circulate steel cuttings out of the wellbore.

- Maintain a minimum annular velocity of 120 ft/min (36.6 m/min).
- Follow Weatherford's drilling mud yield point recommendations, shown in Table 5.
- Avoid oil-based mud whenever possible.
- Ordinarily no difficulty in raising steel cuttings is encountered with common drilling practices. Most difficulties are encountered when a light rig with a small mud pump is used in remedial work. In these cases, add bentonite to the mud so that the effective viscosity becomes sufficient to raise the cuttings.
- If birdnesting occurs around the drillstring, pull up the work string, circulate, and work the pipe until the correct cutting return is achieved. During long milling jobs, repeat the procedure frequently to maintain the ROP.
- Reverse circulation is another way to remove cutting accumulation on the fish. In some cases, boot baskets (junk subs and baskets), reverse circulating junk baskets, or bailers are used to remove or catch steel cuttings.

Table 5—Recommended Drilling Mud Yield Points

Operational Objective	Yield Point (lb/100 ft ²)
Drill	10 to 15
Wash over	15 to 20
Mill	> 30



Junk Milling Operations

Junk mills are often said to be the true workhorses of downhole milling. Use junk mills to mill almost anything in the hole, including:

- Bailers
- Bit cones
- Bits
- Calipers
- Cement
- Collapsed casing
- Drill collars
- Drillpipe
- Hangers
- Jars
- Packers
- Reamers of short lengths
- Setting tools
- Slips
- String shots
- Subs
- Testers
- Wash pipe

When tubulars are cemented inside and out, the junk mill is the only effective tool; however, if the tubulars are not collapsed and the ID is open, a pilot mill might be a better option. A skirted junk mill assembly or a skirted pilot mill assembly often yields better results.

General Recommendations

For optimal performance when milling loose junk, use a junk mill dressed with crushed tungsten carbide. Under some conditions, operations can be improved by spudding, which pounds the junk onto the bottom, breaks it into smaller pieces, and positions it for more effective milling.

Do not allow a sliver of junk to lodge next to the mill—indicated by a noticeable increase in torque and pickup drag. Force the sliver down by spudding the mill.

Pick up the mill and spud the work string periodically to decrease the likelihood of a deep wear pattern developing on the face of the mill. Spudding forces a new wear pattern to develop so that the mill face wears evenly.

Procedures

The procedures for milling loose and stationary junk, in open or cased hole, are basically the same. The few differences are shown in Table 6.

In open hole the junk mill is usually dressed rough OD so that it can cut formation in undersized hole sections; however, in cased hole the junk mill is dressed smooth OD to minimize damage to the interior surface of the casing.

Milling is usually by torque—not by weight applied to the junk or fish.

Table 6—Differences among Junk Milling Procedures

	Loose Junk	Stationary Junk
Open Hole	Use a junk mill that is dressed with crushed tungsten carbide	Use a junk mill that is dressed with CustomCut™ carbide inserts.
	• Use a junk mill with a rough OD that is 1/8 in. smaller than the hole size. • Run a stabilizer, with an OD equal to the size of the junk mill, directly above the junk mill.	
Cased Hole	Use a junk mill that is dressed with crushed tungsten carbide.	Use a junk mill that is dressed with CustomCut carbide inserts.
	• Use a junk mill with a smooth-OD head of the same size as the drift diameter of the casing. • To reduce the risk of damage to the casing, ensure that the junk mill has stabilizer pads that are of the same OD as the mill head. • Run a stabilizer, with an OD equal to the size of the junk mill, directly above the junk mill.	

Junk Milling Operations

Milling Junk or Fish

1. Run at least one boot basket (two boot baskets are recommended) directly above the junk mill. Boot baskets for 4 3/4-in. and smaller drill collars are not strong enough for repeated long periods of spudding.
2. Use sufficient drill collar weight for milling weights to be applied and to overcome pump-off forces.
3. Trip in the hole to within 30 ft (9.1 m) of the junk or fish.
4. Break circulation, and take the up and down weights of the work string with the pumps on and with the pumps off.
5. While circulating, slowly lower the work string without rotating it.
6. Tag the top of the junk or fish with 5,000 lb (2,268 kg) of down weight.
7. Mark the pipe or kelly at the top of the kelly bushing or rotary table.
8. Pick up the work string 5 to 10 ft (1.5 to 3 m) above pickup weight.
9. While rotating the work string, slowly lower it.

Important: Rotary speed is dependent on SFPM for the junk mill OD. Refer to Table 2 (Page 6).

10. Tag the top of the junk or fish, and begin milling with weight on the mill as shown in Table 3 (Page 6). Set down on the junk or fish while rotating the work string, and add milling weight to the junk or fish without delay.
11. Mill with weight on the mill as shown in Table 3.

Important: Do not apply weight first and then rotate. This sequence can damage the cutting structure face of the junk mill. Do not set down on the fish or junk with a light weight and spin. Spinning in one spot on the junk or fish can cause the steel to work-harden; as a result, restarting to mill junk or fish can be difficult.

12. After each 3 to 5 ft (0.9 to 1.5 m) of junk or fish milled, pick up the junk mill 10 to 15 ft (3.0 to 4.6 m), and ream the hole back down to the junk or fish.
13. To stop milling, simply pick up the junk mill off bottom.



Junk Milling Operations

Spudding on Loose Junk

1. Determine the top of the junk, and mark the pipe or kelly at the top of the kelly bushing or rotary table.
2. Pick up the work string 4 to 6 ft (1.2 to 1.8 m) above the pickup weight.
3. Drop the work string, and catch it with the brake 18 to 20 in. (457 to 508 mm) above the top of the junk at the mark on the pipe or the kelly. Do not slow down, but catch the string with a sudden stop. For example, pick up the work string 10 ft (3 m), and drop it 8.5 ft (2.6 m). This step causes the string to stretch and spud the junk on bottom forcefully while the string is still in a state of tension, preventing damage to the string that could be expected if the string were in compression at the moment of impact.
4. Spud the junk three or four times, rotating the junk mill one-quarter turn each time between drops or rotating the work string while spudding on the junk.
5. While rotating it slowly, lower the work string to the top of the junk. Continue milling on loose junk by torque rather than by weight applied to junk.

Junk Mills and Accessories

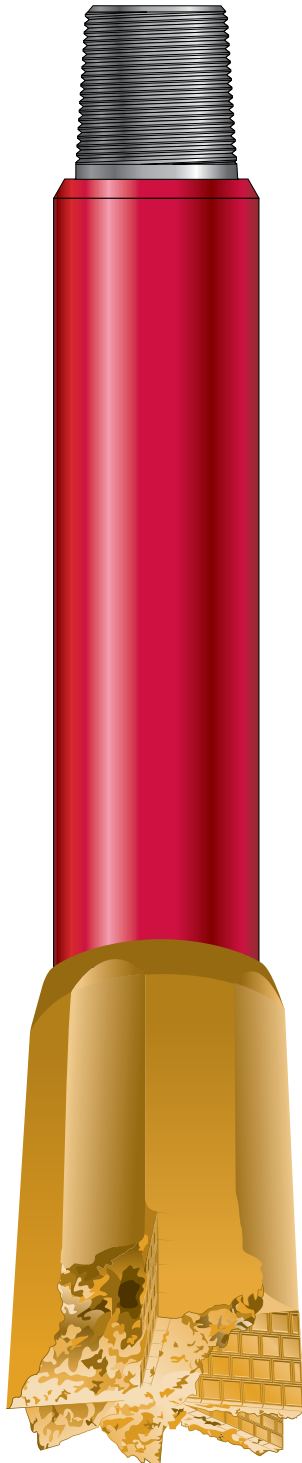
Weatherford junk mills, dressed with crushed tungsten carbide or CustomCut™ tungsten carbide inserts, mill through the toughest drilling materials.

Ordering Information

To ensure delivery of the proper junk mill for your application, include the following information:

- Type of mill (bladed, cone buster, or type P)
- Mill OD
- Smooth or rough mill OD
- Mill dressed with crushed tungsten carbide or CustomCut tungsten carbide inserts
- Size and weight of casing through which the mill is to be run, if available
- Top pin connection

Junk Milling Operations



Bladed Junk Mills

Al-Shaheen offers a full line of standardized bladed junk mills, designed to mill any type of junk or debris from the wellbore. These “workhorses” of downhole milling operations can be dressed either with CustomCut™ tungsten carbide inserts, for stationary fish or junk, or with crushed tungsten carbide, for loose fish or junk. Large circulation ports and watercourses improve fluids circulation for cooling and facilitate cuttings removal. Bladed junk mills can be ordered for any length and OD to meet the specific requirements of the job.

Our bladed junk mills are products of MillSmartSM technology—an engineered approach to milling that encompasses a wide range of proven products, services, and technical resources, developed and refined by the world’s largest and most experienced provider of milling and fishing services.

Applications

- Milling almost anything in the wellbore, including, but not limited to: bit cones, bits, cement, packers, squeeze tools, perforating guns, drillpipe, tool joints, reamers, and reamer blades

Features, Advantages and Benefits

- Rugged, durable construction extends milling time per trip for maximized milling efficiency.
- Crushed tungsten carbide dressing, used for milling loose fish or junk, extends the life of the mill.
- CustomCut tungsten carbide inserts, used for milling stationary fish or junk, improve penetration rates and milling footage.
- Extra-long mill heads minimize risk of casing damage.
- Large circulation ports and watercourses improve cooling during milling operations and provide better fluids circulation and cuttings removal for optimal milling efficiency.
- Mill-head design customization capability provides milling solutions for the full range of open hole, casing, and tubing sizes and weights.
- Smooth OD reduces risk of casing damage in cased-hole wellbores.



Junk Milling Operations

Options

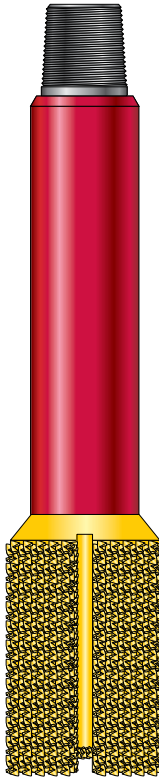
- Concave, convex, and flat-bottom designs available
- Dressed with CustomCut™ tungsten carbide inserts for stationary fish or junk
- Dressed with crushed tungsten carbide for loose fish or junk
- Various lengths of fishing necks, stabilizers, and combination stabilizer-fishing necks available
- Smooth OD for cased-hole wellbores
- Rough OD for openhole wellbores
- Can be ordered for any length and OD to meet job-specific requirements

Specifications

Bladed Junk Mills

Standard Junk Mill OD (in./mm)	Standard Top Pin Connection (API Reg.) (in.)	Standard Fishing Neck		Approximate Weight (lb/kg)
		Length (in./mm)	OD (in./mm)	
3-1/2 to 4-1/2 88.9 to 114.3	2-3/8	12 305	3-1/8 79.4	45 21
4-1/2 to 5-1/2 114.3 to 139.7	2-7/8	12 305	3-3/4 95.3	62 28
5-1/2 to 6 139.7 to 152.4	3-1/2	12 305	4-1/4 108.0	95 43
5-3/4 to 7-1/2 146.1 to 190.5	3-1/2	12 305	4-3/4 120.7	105 48
7-1/2 to 9 190.5 to 228.6	4-1/2	12 305	5-3/4 146.1	180 82
9-1/2 to 12-1/4 241.3 to 311.2	6-5/8	12 305	7-3/4 196.9	350 159
13 to 15 330.2 to 381.0	6-5/8 or 7-5/8	12 305	7-3/4 or 9-1/2 241.3 or 196.9	500 227
17 to 17-1/2 431.8 to 444.5	6-5/8 or 7-5/8	12 305	7-3/4 or 9-1/2 241.3 or 196.9	625 283
18-1/2 to 26 469.9 to 660.4	6-5/8 or 7-5/8	12 305	7-3/4 or 9-1/2 241.3 or 196.9	1,200 544

Junk Milling Operations



Flat-Bottom (Cone-Buster) Mills

Cone-buster junk mills are designed for use in milling and spudding operations to clean up loose junk in wellbores. The spudding action pounds loose junk onto the bottom of the wellbore, breaking the junk into smaller pieces and positioning it for more effective milling.

Cone-buster junk mills can be ordered for any OD to meet job-specific requirements.

Features, Advantages and Benefits

- Large circulation ports and watercourses enable improved fluid circulation and cutting removal, saving time.
- Slightly concave mill-head bottom restricts fish to the center of the mill head for better access control.
- Mills can be dressed smooth OD for cased-hole wellbores and rough OD for openhole wellbores for greater versatility.
- Milling solutions cover the full range of casing and tubing sizes and weights.

Specifications

Flat-Bottom (Cone-Buster) Mills

Standard Flat Bottom (Cone Buster) Mill OD (in./mm)	Standard Top Pin Connection (API Reg.) (in.)	Standard Fishneck Length (in./mm)	Standard Fishneck Diameter (in./mm)	Approximate Weight (lb./kg)
3-1/2 to 4-1/2 88.90 to 114.30	2-3/8	12 305	3-1/8 79.37	45 20.4
4-1/2 to 5-1/2 114.30 to 139.70	2-7/8		3-3/4 95.25	62 28.1
5-1/2 to 6 139.70 to 152.4	3-1/2		4-1/4 107.95	95 43.1
5-3/4 to 7-1/2 146.05 to 190.50			4-3/4 120.65	105 47.6
7-1/2 to 9 190.50 to 228.60	4-1/2		5-3/4 146.05	180 81.7
9-1/2 to 12-1/4 241.30 to 311.15	6-5/8		7-3/4 196.85	350 158.8
13 to 15 330.20 to 381.00	6-5/8 or 7-5/8		7-3/4 or 9-1/2 196.85 or 241.30	500 226.8
17 to 17-1/2 431.80 to 444.50				625 283.5
18-1/2 to 26 469.90 to 660.40				1,200 544.3



Junk Milling Operations

Type P Junk Mill

The type P junk mill is used for milling junk and debris from the wellbore; but its durability also gives it the longer life needed for milling cemented tubulars. An offset center prevents coring of the mill during milling operations. The special deep-V design maximizes fluids circulation to provide better cooling and more efficient removal of cuttings. The type P junk mill can be ordered in any length and OD to meet job-specific requirements. The type P junk mill is usually dressed with crushed tungsten carbide but under special applications is dressed with CustomCut™ inserts.

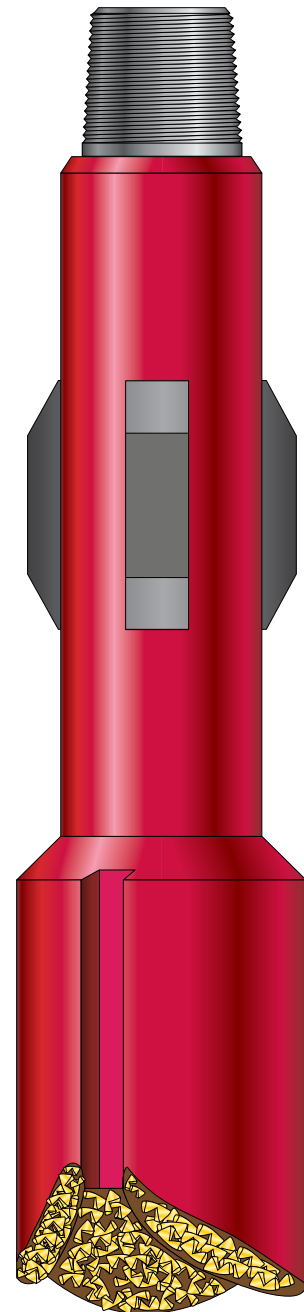
The type P junk mill is a product of MillSmartSM technology—an engineered approach to milling that encompasses a wide range of proven products, services, and technical resources, developed and refined by the world's largest and most experienced provider of milling and fishing services.

Applications

- Milling junk, debris, and cemented tubulars

Features, Advantages and Benefits

- Offset center prevents coring of the mill during milling operations, extending mill life and saving equipment costs.
- Deep-V design provides a larger circulating total flow area for better cooling of the carbide cutting structure and more efficient cuttings removal.
- The mill can be dressed for open or cased hole to suit job-specific requirements.



Junk Milling Operations

Specifications

Type P Junk Mill

Mill			Standard Fishing Neck	
Body OD (in./mm)	Standard Top Pin Connection	Approximate Shipping Weight (lb/kg)	Length (in./mm)	OD (in./mm)
3-1/2 to 4-1/2 88.9 to 114.3	2 3/8-in. Reg	45 20	12 304.8	3-1/8 79.4
4-1/2 to 5-1/2 114.3 to 139.7	2 7/8-in. Reg	62 28	12 304.8	3-3/4 95.3
5-1/2 to 6 139.7 to 152.4	3 1/2-in. Reg	95 43	12 304.8	4-1/4 108.0
5-3/4 to 7-1/2 146.1 to 190.5	3 1/2-in. Reg	105 48	12 304.8	4-3/4 120.7
7-1/2 to 9 190.5 to 228.6	4 1/2-in. Reg	180 82	12 304.8	5-3/4 146.1
9-1/2 to 12-1/4 241.3 to 311.2	6 5/8-in. Reg	350 159	12 304.8	7-3/4 196.9
13 to 15 330.2 to 381.0	6 5/8- or 7 5/8-in. Reg	500 227	12 304.8	7-3/4 or 9-1/2 241.3 or 196.9
17 to 17-1/2 431.8 to 444.5	6 5/8- or 7 5/8-in. Reg	625 284	12 304.8	7-3/4 or 9-1/2 241.3 or 196.9
18-1/2 to 26 469.9 to 660.4	6 5/8- or 7 5/8-in. Reg	1,200 544	12 304.8	7-3/4 or 9-1/2 241.3 or 196.9



Junk Milling Operations

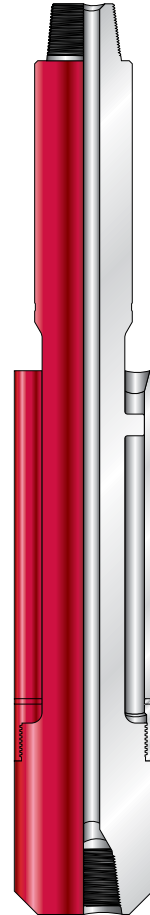
Screw-on-Skirt Boot Basket

The screw-on-skirt boot basket catches debris and junk that is too heavy to circulate out of the wellbore. Designed for use in the drill collar string, just above a milling tool or drill bit, the boot basket consists of an oversized skirt screwed onto a steel mandrel with a left-hand thread. The screw-on skirt allows easy access to the mandrel for inspection of both skirt and mandrel.

Except in highly deviated holes, Al-Shaheen recommends running two boot baskets in tandem to decrease the likelihood of junk bypassing a single basket.

Features, Advantages and Benefits

- Tandem operation of boot baskets increases junk-catching capacity for greater operational efficiency.
- Removable skirt enables quick and easy inspection of skirt and mandrel for more thorough tool inspection and maintenance.
- Integral skirt support ribs eliminate the need for welding the skirt or the mandrel, enhancing basket reliability.
- Standard box-down, pin-up connections enable running above a mill or drill bit.
- Drain holes in the skirt enable the wellbore fluids to drain after the boot basket is brought out of the hole to surface.



Screw-on-Skirt Boot Basket

Recommended Hole Size (in./mm)	Standard Skirt Diameter (in./mm)	Top and Bottom Connections (in./mm)	Overall Length (in./mm)	Fishneck Diameter (in./mm)	Body Diameter Under Sleeve (in./mm)	Bore Diameter (in./mm)	Sleeve Length (in./mm)	Approximate Weight (in./mm)
4-1/8 to 4-1/2 104.8 to 114.3	3-11/16 93.7	2-3/8 60.3	33 838	3-1/8 79.4	2 50.8	1 25.4	10-1/2 266.7	50 23
4-5/8 to 4-7/8 117.5 to 123.8	4 93.7	2-3/8 60.3	33 838	3-1/2 88.9	2 50.8	1 25.4	10-1/2 266.7	62 28
		2-7/8 73.0	37 940	4 101.6	2-1/2 63.5			66 30
5 to 5-3/4 127.0 to 146.0	4-1/2 114.3	2-7/8 73.0	37 940	4 101.6	2-1/2 63.5	1 25.4	10-1/2 266.7	91 41
5-7/8 to 6-3/8 149.2 to 161.9	5 127.0	3-1/2 88.9	38 965	4-5/8 117.4	3-1/4 82.5	1-1/2 38.1	10-1/2 266.7	120 54
6-1/2 to 7-3/8 165.1 to 187.3	5-1/2 139.7			5 127.0	3-1/4 82.5			144 65
7-1/2 to 8-1/2 190.5 to 215.9	6-1/2 165.1	4-1/2 114.3	48 1,219	6-1/2 165.1	4-1/4 107.9	2 50.8	10-1/2 266.7	261 118
	6-5/8 168.3							270 122
8-5/8 to 9-5/8 219.1 to 244.5	6-3/4 171.5							280 127
	7 177.8	6-5/8 168.3	50 1,270	7-1/2 190.5	5-1/2 139.7	3 76.2	10-1/2 266.7	298 135
9-5/8 to 11-3/8 244.5 to 288.9	8-1/2 215.9							438 199
	8-5/8 219.1							451 205
11-1/2 to 13 292.1 to 330.2	9-5/8 244.5	7-5/8 193.7	51 1,295	8-1/2 215.9	7-1/2 190.5	2-13/16 71.4	17 431.8	529 240
14 to 17-1/2 355.6 to 444.5	10-3/4 273.1			9-5/8 244.5				806 366
	12-3/4 323.9			11 279.4				1,065 483

Pilot Milling Operations

Pilot Milling Operations

Pilot mills have either a diamond point, with a pilot, or a lower connection below the milling blades. Use pilot mills on the following:

- Casing
- Liners, hangers, and adaptors
- Wash pipe
- Drillpipe and drill collars
- Tubing

The pilot of the mill can be dressed to mill any junk encountered inside the fish.

General Recommendations

Select a pilot mill with a blade OD that is 1/4 in. larger than the OD of the tool joint or coupling of the fish milled. The pilot OD should be the same as the drift ID of the fish.

The optimal speed and weight for running a pilot mill will vary from job to job, even in the same well. Different conditions may require different rotary speeds and weights. In the absence of experience, start with a speed of 80 to 100 RPM and a tool weight of 2,000 to 6,000 lb (907 to 2,722 kg). Adjust the speed and weight to obtain the best results.

To mill a liner or casing that is perforated, damaged with a spear, or collapsed, use 60 RPM and 2,000 lb (907 kg) of weight or less.

A sudden drop in milling rate during the milling of swaged casing may be caused by a loose ring of steel formed at a joint or weld, which turns with the pilot mill. Gently spud the mill to break up the ring and help position it for milling.

If cutting stops during the milling of wash pipe, casing, or liner, without a noticeable increase in torque, the fish could be turning. If so, pull the mill, and retrieve the fish with a spear.

Application-Specific Recommendations

Liners, Hangers and Adaptors

Liner hangers can be milled efficiently, eliminating the need for inside cuts and the running of spears or jars for recoveries. For most liner milling jobs, first use a pilot mill to mill the liner hanger or adaptor and then the liner; however, if the ID of the hanger or adaptor is smaller than the ID of the liner, use a junk mill, then mill the liner with a pilot mill. The pilot mill is preferred if hard cement is behind the liner or if the hanger has numerous bow springs and slips. Select a pilot mill with blades of the correct OD for the pipe couplings.

Wash Pipe

The pilot mill is the most efficient tool for milling stuck wash pipe; however, if drillpipe or drill collars are inside the wash pipe, first fish them out or mill them with a junk mill or smaller pilot mill.



Pilot Milling Operations

Drillpipe and Drill Collars

Drillpipe and drill collars are milled with pilot mills if the ID is open. If the pipe is cemented inside the casing, particularly in deviated holes, the pipe is probably lying to one side, eccentric to the casing. This position usually makes the job difficult with a pilot mill; but using a smaller-OD pilot will allow the pilot mill to move away from the casing ID. Otherwise, a full-gauge junk mill is recommended. A pilot mill performs reasonably on collars if the cuttings are removed as milling progresses. If the cuttings tend to fall into the ID and plug it, use a full-gauge junk mill.

Casing and Tubing

Use a pilot mill to mill casing and tubing as you would to mill wash pipe.

Procedure

To mill J-55 or K-55 material, use a weight of 4,000 to 6,000 lb (1,814 to 2,722 kg) and a speed of 125 RPM. For N-80 and P-110 material, use a weight of 8,000 to 10,000 lb (3,629 to 4,536 kg) and a speed of 125 RPM. Refer to Tables 2 and 3 (Page 6) for calculation of surface feet per minute (SFPM) and weight on mill, respectively.

If the casing is surrounded by hard cement, or if the openhole diameter is the same as or less than the blade OD of the mill, more weight may be needed to drill cement or the formation in addition to the fish.

1. Lower the mill to about 5 ft (1.5 m) above the fish.
2. Set the brake, rotate, and break circulation.
3. Slowly increase the rotation to 125 RPM.
4. Take parameters of up and down weights. This step tells you the neutral weight of the string and enables you to note the normal torque in the string. By noting the torque in the string when the pilot enters the fish, you can determine whether the pilot entered correctly.
5. Slowly lower the string until the milling blades contact the top of the fish; then begin milling. Important: When working below the casing shoe, ream the hole up and down after every 20 to 30 ft (6 to 9 m) of fish milled to clean out any cuttings accumulated at the shoe. Periodic reaming to ensure cutting removal is also a good practice in holes with drift angles of 30° or more.
6. Continue milling at an even rate, without interruption. Do not reweigh the string at short intervals, but keep an even rate of string weight on the pilot mill while milling.

Pilot Mills

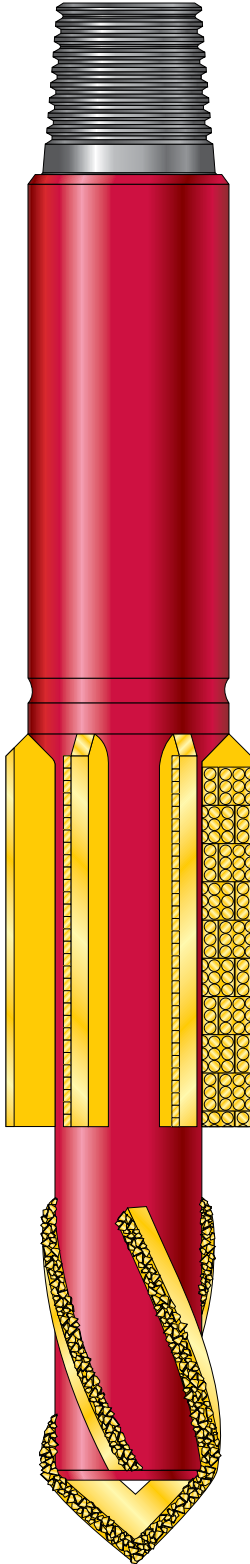
Pilot mills, dressed with CustomCut™ tungsten carbide inserts, are recommended for milling casing, tubing, wash pipe, drillpipe, drill collars, crossover swages, liners, hangers, and adaptors.

Ordering Information

To ensure delivery of the proper pilot mill for your application, include the following information:

- Type of mill (diamond point or lower-connection type)
- Size and weight of casing to be milled
- Top pin connection
- OD and ID of tubulars to be milled

Pilot Milling Operations



CustomCut™ Pilot Mill (Diamond Point)

The CustomCut diamond-point pilot mill can be used to mill a full range of tubular products. The mill consists of a leading stabilizer (the pilot), which is sized for the ID of the tubular, and a major diameter section, sized at least 1/4 in. larger than the coupling OD. The CustomCut diamond-point mill can be dressed with crushed carbide or with one of the family of CustomCut inserts, as appropriate for the application.

The CustomCut diamond-point pilot mill is a product of MillSmartSM technology—an engineered approach to milling that encompasses a wide range of proven products, services, and technical resources, developed and refined by the world's largest and most experienced provider of milling and fishing services.

Applications

- The CustomCut diamond-point pilot mill is used for milling tubing, casing, liner hangers, liners, drillpipe, drill collars, wash pipe, or perforated liners.
- CustomCut inserts that are specifically tailored to the operation and to the capabilities of the surface equipment. For surface equipment or fluids with limited capabilities, CustomCut 100 series inserts produce small, lightweight cuttings. For premium fluids and high-volume surface equipment, CustomCut 200 and 300 series inserts maximize milling rates and the life of the pilot mill.

Features, Advantages and Benefits

- Full OD ensures that collars are milled in the same operation, eliminating creation of junk in the wellbore and extending the life of the pilot mill.
- Optimized alignment of CustomCut insert to proper cutting angle produces smaller cuttings for better wellbore cleaning and longer life of the mill.
- Longer blades extend downhole cutting time and the life of the mill.
- Insert selection capability optimizes the mill design to the composition of the tubular being milled and the capabilities of surface facilities, resulting in higher rates of penetration.



Pilot Milling Operations

Specifications

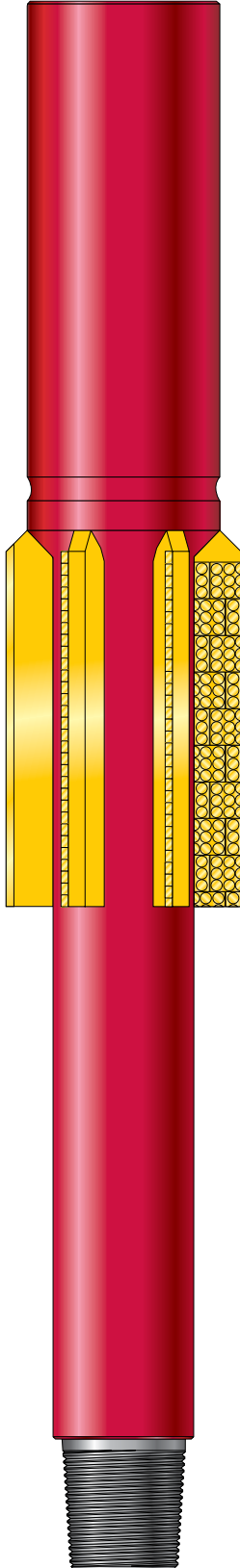
CustomCut Pilot Mill
(Diamond Point)

Casing Size (in.)	Top Pin Connection	Mill Blade OD
		(in./mm)
4-1/2	3-1/2-in. Reg.	5.250 133.350
5		5.813 147.650
5-1/2		6.300 160.020
6		6.875 174.625
6-5/8	4-1/2-in. Reg.	7.640 194.056
7		7.916 201.066
7-5/8		8.750 222.250
8-5/8	6-5/8-in. Reg.	9.875 250.825
9-5/8		10.875 276.225
10-3/4		12.000 304.800
11-3/4		13.000 330.200
13-3/8		14.625 371.475

Selection Guide for CustomCut Inserts
(Diamond-Point Pilot Mill)

Applications	Inserts
Surface equipment or fluids with limited capabilities	100C
	101C
High-volume surface equipment and premium fluids	200M
	201M
	202M
	203M
	300M
	301M
	302M
	303M
	304M

Pilot Milling Operations



CustomCut Pilot Mill (Lower-Connection Type)

Weatherford's CustomCut lower-connection type pilot mill can be used to mill a full range of tubular products. This versatile tool is run above a taper mill; but an optional stabilizer can also be run with the taper mill as the pilot, which is sized for the ID of the tubular. In addition, drill collars can be run below the mill for milling weight in shallow-well applications. The major diameter section of the lower-connection type pilot mill is sized at least 1/4 in. larger than the coupling OD, eliminating creation of junk in the wellbore and extending the life of the pilot mill. The CustomCut lower-connection type pilot mill is dressed with one of the family of CustomCut inserts, as appropriate for the application.

Weatherford's lower-connection type CustomCut pilot mill is a product of the company's MillSmartSM technology—an engineered approach to milling that encompasses a wide range of proven products, services, and technical resources, developed and refined by the world's largest and most experienced provider of milling and fishing services.

Applications

- The CustomCut lower-connection type pilot mill is used for milling tubing, casing, liner hangers, liners, drillpipe, drill collars, wash pipe, or perforated liners.
- CustomCut inserts are specifically tailored to the operation and to the capabilities of the surface equipment. For surface equipment or fluids with limited capabilities, CustomCut 100 series inserts produce small, lightweight cuttings. For premium fluids and high-volume surface equipment, CustomCut 200 and 300 series inserts maximize milling rates and the life of the pilot mill.

Features, Advantages and Benefits

- Full OD ensures that collars are milled in the same operation, eliminating creation of junk in the wellbore and extending the life of the pilot mill.
- Optimized alignment of CustomCut insert to proper cutting angle produces smaller cuttings for better wellbore cleaning and longer life of the mill. Longer blades extend downhole cutting time and the life of the mill. Pin-down design facilitates the optimal, operation-specific bottomhole assembly
- to increase pilot milling success.
- Insert selection capability optimizes the mill design to the composition of the
- tubular being milled and the capabilities of surface facilities, resulting in higher rates of penetration.



Pilot Milling Operations

Specifications

CustomCut Pilot Mill
(Lower-Connection Type)

Casing Size (in.)	Top Pin Connection	Mill Blade OD
		(in./mm)
4-1/2	3-1/2-in. Reg.	5.250 133.350
5		5.813 147.650
5-1/2		6.300 160.020
6		6.875 174.625
6-5/8	4-1/2-in. Reg.	7.640 194.056
7		7.916 201.066
7-5/8		8.750 222.250
8-5/8	6-5/8-in. Reg.	9.875 250.825
9-5/8		10.875 276.225
10-3/4		12.000 304.800
11-3/4		13.000 330.200
13-3/8		14.625 371.475

Selection Guide for CustomCut Inserts (Lower-
Connection Type Pilot Mill)

Applications	Inserts
Surface equipment or fluids with limited capabilities	100C
	101C
High-volume surface equipment and premium fluids	200M
	201M
	202M
	203M
	300M
	301M
	302M
	303M
	304M

Taper Milling Operations

Taper Milling Operations

Use taper mills to eliminate restrictions or to mill through pinched, collapsed casing. The mills have either a tapered or a short, blunt nose that serves as a guide. The type of restriction type dictates which type of taper mill to use.

Weatherford's standard taper mill is designed for milling through restrictions. The spiral blades and pointed nose, dressed with crushed tungsten carbide, make this mill ideal for reaming collapsed casing and liners, cleaning permanent whipstock windows, milling through jagged or split guide shoes, and enlarging restrictions through retainers and adaptors.

The blunt-nose taper mill is effective in rough conditions that can cause longer, tapered mills to break. The blunt-nose mill generates less torque than a conventional taper mill as a result of its shorter section. With the lower torque, the blunt-nose mill can be run with more weight, when required, for operations such as milling plate or solid junk.

General Recommendations

The torque encountered governs milling speed. To overcome torque challenges, do not exceed 75 RPM. Do not rotate a taper mill resting on a fish. Doing so can further damage the fish. Enter the fish with a rotary speed of 75 RPM or less. Use less weight when running a taper mill than a junk or pilot mill. After entering the fish, slowly increase the tool weight to 1,000 to 2,000 lb (454 to 907 kg), and avoid torque increase.

Procedures

The procedure for using a taper mill varies, depending on the application.

Cleaning a Whipstock Window

Use a taper mill of the same diameter as the largest mill used to mill the window or slightly larger than the bit used.

1. Run the taper mill into the hole to within 5 ft (1.5 m) of the window top.
2. Start the rotary table, and rotate at approximately 40 RPM down to the whipstock face.
3. Keep the weight under 1,000 lb (454 kg). Excessive weight can cause the taper mill to slip out of the window prematurely.
4. Rotate slowly with a light weight down the full length of the whipstock face. Do not try to make hole with the tool.
5. To clean all the rough edges, repeat Steps 2 through 4 several times, until the mill runs smoothly for the full length of the whipstock.



Taper Milling Operations

Reaming Collapsed Casing

1. Determine the approximate diameter of the collapsed casing by passing an impression block or bit through the collapsed interval. Do not use a taper mill if the collapsed interval has passed the center. (See Step 4.)
2. Use a taper mill that is about 1/4 in. larger than the minimum ID of the collapsed section, and mill the collapsed interval by stages. If the collapse is significant, use mills of several different sizes to bring the ID of the pipe to the full gauge and minimize any sidetracking tendency.
Important: Use a string mill if any danger of sidetracking exists. The casing conditions govern the length and diameter of the mill. If used, the tool only reams.
3. Mill at a table speed of approximately 50 RPM. The torque encountered governs the milling weight—usually 2,000 to 3,000 lb (907 to 1,361 kg).
4. If the collapse is significant, the lower portion of the collapsed interval may act as a whipstock. The taper mill may cut through the upper portion of the interval and be deflected into the formation by the lower section of the damaged casing. Run a stabilizer and rigid hookup with a junk mill. Use a light weight with a table speed of about 125 RPM to mill the collapsed portion and enter the undamaged casing below. Step 2 suggests another approach if an opening is large enough to admit tubing or a macaroni string through the collapsed interval.

Enlarging Restrictions through Retainers and Adaptors

Use a taper mill with a diameter equal to the desired enlargement, usually the drift ID of the string.

1. Mill through the restriction at approximately 70 RPM, with the weight from 2,000 to 6,000 lb (907 to 2,722 kg). The torque governs the speed and weight. If the torque is high, reduce the speed and weight until the mill turns freely.
2. Increase the speed to 80 to 100 RPM. Rotate up and down through the interval several times until it is smooth and free.

Reaming Guide Shoes

In some cases, the bull plug on the bottom of liners or casing may be jagged or split so that the drilling string hangs as it is pulled out of the hole. This condition can usually be remedied by reaming through the guide shoe with a taper mill. Use the procedure in “Enlarging Restrictions through Retainers and Adaptors.”

Taper Milling Operations

Taper Mills

Weatherford's taper mills are available in standard sizes or can be special ordered to any length and OD to meet job-specific requirements.

Ordering Information

- To ensure delivery of the proper taper mill for your application, include the following information:
- Type of taper mill (standard or blunt-nose)
- Taper mill OD
- Smooth or rough OD
- Size and weight of casing to be milled
- Top pin connection



Taper Milling Operations

Taper Mills

Weatherford's taper mills are used to mill out restrictions in collapsed casing and liner sections, mill through jagged or split guide shoes, enlarge restrictions through retainers and adaptors, and de-burr whipstock windows.

The lower taper section guides the mill into the collapsed section. Then the slightly spiraled blades, dressed with crushed tungsten carbide, mill away the undersized section to full taper mill diameter. The full-bore ID improves fluids circulation for cooling and facilitates cuttings removal.

Taper mills are available in standard sizes or can be special ordered to any length and OD to meet the specific requirements of the job.

Weatherford's taper mills are products of the company's MillSmartSM technology—an engineered approach to milling that encompasses a wide range of proven products, services, and technical resources, developed and refined by the world's largest and most experienced provider of milling and fishing services.

Applications

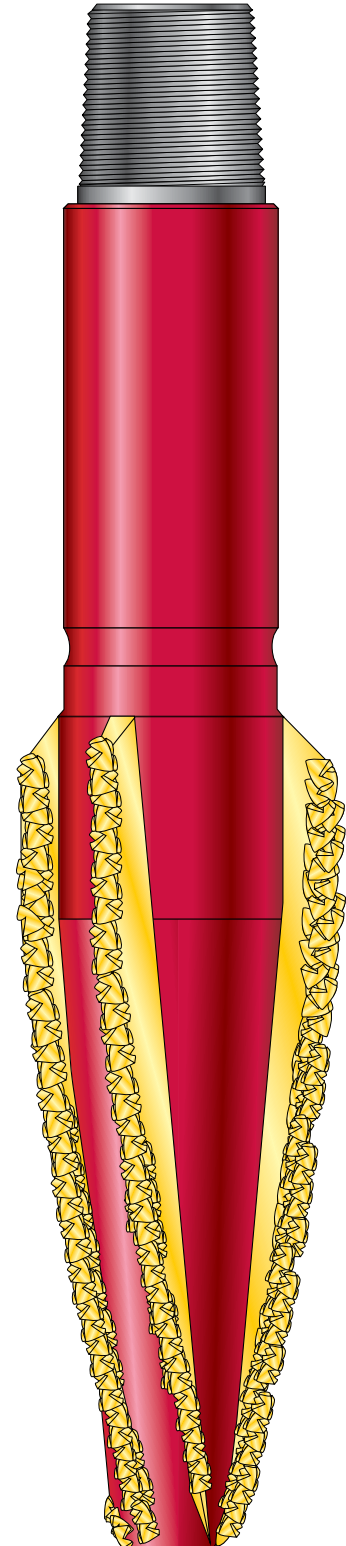
- Milling out restrictions in collapsed casing and liner sections of any size and weight
- Milling through jagged or split guide shoes
- Enlarging restrictions through retainers and adaptors
- De-burring whipstock windows

Features, Advantages and Benefits

- Crushed tungsten carbide-dressed blades mill the section to full taper mill diameter. Full-bore ID improves better fluids circulation, cooling during milling, cuttings removal, and overall milling efficiency.
- Design customization capability, including length, OD size, and smooth- or rough-OD option, provides solutions for the full range of casing and tubing sizes and weights.

Options

- Length and OD can be customized to suit job-specific requirements.
- The mill can be dressed with a smooth or rough OD, as required.
- Crushed tungsten carbide-dressed blades are standard. CustomCut™ inserts can be added to retain the gauge OD of the mill.



Taper Milling Operations

Specifications

Standard Taper Mill OD (in./mm)	Standard Top Pin Connection (API Reg.)	Standard Fishing Neck		Approximate Weight (lb/kg)
		Length (in./mm)	OD (in./mm)	
3-1/2 to 4-1/2 88.9 to 114.3	2-3/8	12 304.8	3-1/8 79.4	45 20
4-1/2 to 5-1/2 114.3 to 139.7	2-7/8		3-3/4 95.3	62 28
5-1/2 to 6 139.7 to 152.4	3-1/2		4-1/4 108.0	95 43
5-3/4 to 7-1/2 146.1 to 190.5			4-3/4 120.7	105 48
7-1/2 to 9 190.5 to 228.6	4-1/2		5-3/4 146.1	180 82
9-1/2 to 12-1/4 241.3 to 311.2	6-5/8		7-3/4 196.9	350 159
13 to 15 330.2 to 381.0	6-5/8 or 7-5/8		7-3/4 or 9-1/2 241.3 or 196.9	500 227
17 to 17-1/2 431.8 to 444.5				625 283
18-1/2 to 26 469.9 to 660.4				1,200 544



Watermelon/String Milling Operations

Watermelon/String Milling Operations

Use watermelon/string mills to mill collapsed areas in casing and liners, eliminate key seats and doglegs, and extend whipstock windows. Multiple watermelon/string mills can be run throughout the drillstring, as required.

Watermelon/String Mills

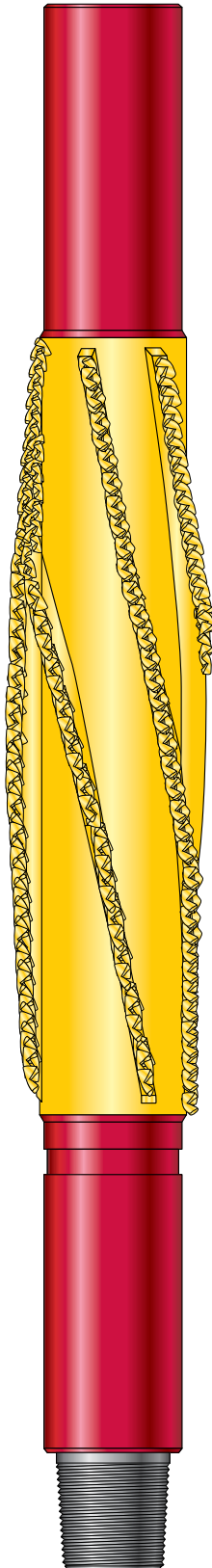
Weatherford's watermelon/string mills are available in standard sizes or can be special ordered to any length and OD to meet job-specific requirements.

Ordering Information

To ensure delivery of the proper watermelon/string mill for your application, include the following information:

- Type of mill (watermelon or string)
- Mill OD
- Smooth or rough OD
- Size and weight of casing to be run through, if available
- Connection sizes

Watermelon/String Milling Operations



Watermelon/String Mills

Weatherford's watermelon/string mills are excellent for milling out collapsed areas in casing and liners, eliminating key seats and doglegs, and extending whipstock windows. Multiple watermelon/string mills can be run throughout the drillstring.

Slightly spiraled blades, dressed with crushed tungsten carbide, are held to close OD tolerances for maximum opening in the casing or key seat. The blades are tapered top to bottom to allow upward and downward reaming.

Watermelon/string mills are available in standard sizes and can be special ordered to any length and OD to meet the specific requirements of the job.

Weatherford's watermelon/string mills are products of the company's MillSmartSM technology—an engineered approach to milling that encompasses a wide range of proven products, services, and technical resources, developed and refined by the world's largest and most experienced provider of milling and fishing services.

Applications

- Milling out collapsed areas in casing and liners
- Eliminating key seats and doglegs in open hole
- Extending whipstock windows

Features, Advantages and Benefits

- Slightly spiraled blades, dressed with crushed tungsten carbide, are held to close OD tolerances for maximum opening in the casing or key seat.
- Top-to-bottom blade tapering allows both upward and downward reaming for increased efficiency.
- Design customization capability, including length, OD size, and smooth- or rough-OD option, provides solutions for the full range of casing and tubing sizes and weights.

Options

- Length and OD can be customized to suit job-specific requirements.
- The mill can be dressed with a smooth or rough OD, as required.
- Crushed tungsten carbide-dressed blades are standard. CustomCut™ inserts can be added to retain the gauge OD of the mill.



Watermelon/String Milling Operations

Specifications

Standard Taper Mill OD (in./mm)	Standard Top Pin Connection (API Reg.)	Standard Fishing Neck		Approximate Weight (lb/kg)
		Length (in./mm)	OD (in./mm)	
3-1/2 to 4-1/2 88.9 to 114.3	2-3/8	12 304.8	3-1/8 79.4	45 20
4-1/2 to 5-1/2 114.3 to 139.7	2-7/8		3-3/4 95.3	62 28
5-1/2 to 6 139.7 to 152.4	3-1/2		4-1/4 108.0	95 43
5-3/4 to 7-1/2 146.1 to 190.5			4-3/4 120.7	105 48
7-1/2 to 9 190.5 to 228.6	4-1/2		5-3/4 146.1	180 82
9-1/2 to 12-1/4 241.3 to 311.2	6-5/8		7-3/4 196.9	350 159
13 to 15 330.2 to 381.0	6-5/8 or 7-5/8		7-3/4 or 9-1/2 241.3 or 196.9	500 227
17 to 17-1/2 431.8 to 444.5				625 283
18-1/2 to 26 469.9 to 660.4				1,200 544

Section Milling Operations

Section Milling Operations

Use section mills for cutting a single string of casing or for cutting sections of casing above and below storage formations, in perforated zones, for squeezing cement to plug old wells, to permit a sidetracking operation, or to allow cement-bonding between new, smaller casing and the formation. Some section mills are used as well to mill internal casing patches, screens, liners, and liner packers.

A variety of specialized features have been developed to enable selection of the optimal section mill for the application.

General Recommendations

Use the lightest weights possible in section milling, consistent with acceptable ROPs, especially if you suspect corroded casing. Take care to prevent splitting the casing during milling.

If the milling rate suddenly drops, a loose ring of steel formed at a joint or weld may be turning with the section mill, preventing it from operating correctly. Gently spud the mill to break up the ring and help position it for milling.

The mill must completely cut through the casing so that the blades can be firmly seated on the casing. When operating a section mill without a flow indicator, prolong the cut-out to ensure complete cut-through.

Several situations can make cutting out difficult. Table 17 presents typical causes of difficulty and Weatherford's recommendations for overcoming them.

Causes of Difficulty in Cutting Out and Their Solutions

Cause	Recommendation
Insufficient pressure at the tool	This situation is the most common cause of difficulties in cutting out, such as not achieving proper knife tip force. Maintain a pressure drop of at least 350 to 750 PSI (2,413 to 5,171 kPa) at the mill orifice (depending on the tool size) to keep the cutting knives open and cut the casing.
Excessive pump surging in the drillstring with subsequent yo-yoing	This situation can cause the mill blades to try to cut the casing over a considerable interval and may interrupt the cut. Decrease the pump rate.
Blocked tool orifice	Lost-circulation material, pieces of drillpipe rubbers, or other substances can block the orifice of the tool, causing it to malfunction or plug the section mill. Ensure that the milling fluid is free of these materials.
Poor cutting returns	A good cutting return is essential, or difficulties, such as birdnesting and plugging, may develop. Watch the shaker for cuttings. To improve the return, increase the flow and mud weight with additives as necessary.



Section Milling Operations

Procedure

1. Make up the tool string, and run in the hole to the depth of the intended cutout.
2. Rotate at 60 to 80 RPM for the cut-out.
3. Start the pumps, and build the pump strokes to the output (gallons or liters per minute) required to give the minimum pressure drop across the piston nozzle of the tool, depending on its size. After the cut-out, the pressure drops 200 to 500 PSI (1,379 to 3,447 kPa), depending on the tool size.
4. After the cut-out, rotate 10 to 15 min to clean the cut.
5. Apply weight, and increase the rotational speed to 150 to 350 SFPM (45.7 to 106.7 SMPM). The most efficient milling weight is usually 2,000 to 9,000 lb (907 to 4,082 kg).
6. After the section is milled or when the knives are worn out, circulate until the hole is clean.
7. Stop the circulation, and rotate for 5 to 10 min for the correct knife closure.
8. Pull the tool into the shoe, and trip out conventionally.

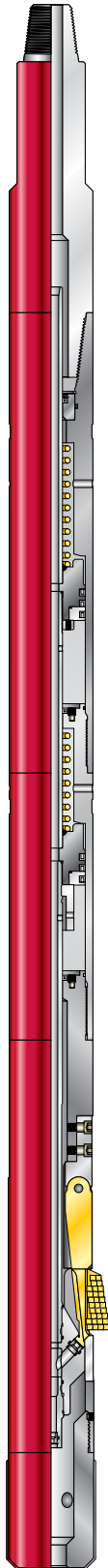
Section Mills

Weatherford offers a variety of section mills to meet job-specific requirements.

Ordering Information

- To ensure delivery of the proper section mill for your application, include the following information:
- Mill OD Size and weight of casing to be milled
- Length of window to be milled
- Top pin connection

Section Milling Operations



A-1 Section Mill

Weatherford's A-1 section mill is an extremely reliable hydraulically activated tool for milling a section of casing or tubing. The mill is simple in design, is easy to operate, and has an outstanding reputation for milling performance. Milling knives are dressed with Weatherford's CustomCut™ tungsten carbide inserts to provide extended milling footage with maximum rates of penetration. The A-1 section mill is available in four different models: single-cylinder, high-flow singlecylinder, dual-cylinder, and high-flow dual-cylinder. The dual-cylinder section mills provide greater hydraulic power to the milling knives for milling depths greater than 10,000 ft (3,048 m). The high-flow section mills keep the cutting structure cool and create a continuous flushing-and-cleaning action on the milling knives.

Weatherford's A-1 section mill is a product of the company's MillSmartSM technology—an engineered approach to milling that encompasses a wide range of proven products, services, and technical resources, developed and refined by the world's largest and most experienced provider of milling and fishing services.

Applications

- Milling of a section of casing
 - above and below storage formations
 - in perforated zones
 - for squeezing cement to plug old wells
 - to allow a sidetracking operation
 - to ensure cement-bonding between new, smaller casing and the formation
 - for plug and abandonment
- Cutting a single string of casing

Features, Advantages and Benefits

- Milling knives are dressed with Weatherford's CustomCut tungsten carbide inserts for longer life and the resulting cost savings.
- Milling knives are available with single blades, for equipment and fluids with limited capabilities, or with double blades, for premium equipment and fluids.
- Various nozzle sizes can be predetermined, using Weatherford's HydraPro™ hydraulics software, to achieve the most productive flow pattern and hole-cleaning capabilities while milling.
- High-flow mills keep the cutting structure cool and create a continuous flushing-and-cleaning action on the milling knives, increasing the life of the equipment and conserving equipment costs.
- Dual-cylinder mills provide more hydraulic power to the milling knives, which allows more efficient penetration rates.



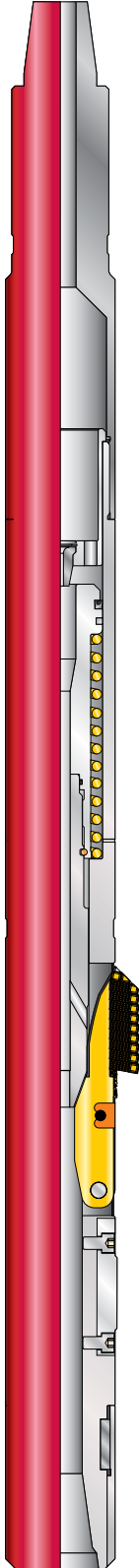
Section Milling Operations

Specifications

Mill				Casing OD (in.)
Body OD (in./mm)	Top Pin connection	Approximate Shipping Weight (lb/kg)	Assembly Number	
4-1/2 114.30	2-7/8-in. API Reg	215 978	10364	5-1/2
5-1/2 139.70	3-1/2-in. API Reg	529 240	10351	6-5/8 to 7
6-1/4 158.75		565 256	10841	7-5/8
7-1/4 184.15	4-1/2-in. API Reg	595 270	10558	8-5/8
8 203.20		911 413	10277	9-5/8
9 228.60		1,070 485	10811	10-3/4
11-3/4 298.45	6-5/8-in. API Reg	1,405 637	10405	13-3/8

API regular pin connections are standard; other connections are available on request. When ordering or requesting quotations on A-1 section mills, state depth of section and size and weight of casing to be milled.

Section Milling Operations



Eliminator® Section Mill

Weatherford's Eliminator section mill is a hydraulically activated tool used to mill sections of casing or tubing. Weatherford designed this mill with an emphasis on simplicity, robustness, ease of maintenance, and ease of operation. Milling knives are dressed with CustomCut™ tungsten carbide inserts to provide extended milling footage with maximum penetration rates.

The most distinguishing feature of the Eliminator mill is the knife configuration. Unlike all other section mills, the Eliminator mill has knives that pivot from the bottom rather than from the top. This feature provides for a full-sweep diameter greater than the diameter of the casing collar—for the entire knife length. When the knives are activated, the Eliminator section mill looks very similar to a pilot mill. The flow indicator incorporated in the design of this mill gives a positive pressure drop at surface when the cutout is made, which prevents “skimming” the ID of the casing.

As with other hydraulic tools with arms, circulation through a restriction in the Eliminator mill creates a pressure drop across a tube, which causes the tube to travel downward with the tool body. The downward travel and a tapered surface on the lower end of the tube force the cutting knives outward. The outward knife movement provides the cutting action into the inner surface of the casing. When cutout through the casing wall is achieved, the knives are fully supported into their outermost position, and cutting proceeds in a downward direction on the upper face of the casing, immediately below the cutout point.

Weatherford's Eliminator section mill is a product of the company's MillSmartSM technology—an engineered approach to milling that encompasses a wide range of proven products, services, and technical resources, developed and refined by the world's largest and most experienced provider of milling and fishing services.

Applications

- Milling of a section of casing
 - above and below storage formations
 - in perforated zones
 - for squeezing cement to plug old wells
 - to permit a sidetracking operation
 - to allow cement-bonding between new, smaller casing and the formation
- Cutting a single string of casing



Section Milling Operations

Features, Advantages and Benefits

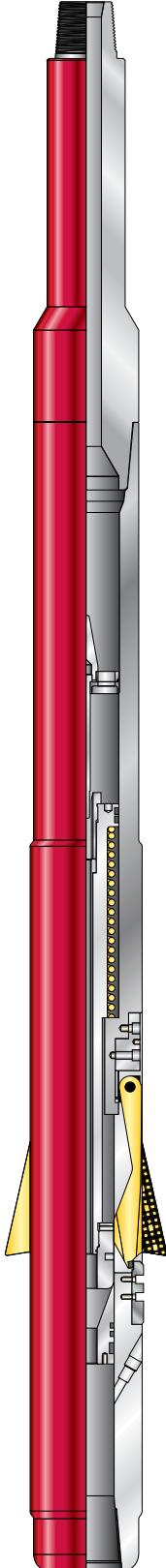
- Reverse-milling knife profile, similar to that of a pilot mill when opened, yields a true OD for the life of the knives, thereby decreasing the number of trips in the hole and providing quicker cutout.
- Integral stabilizer requires fewer connections and is changeable from the rig floor, saving redress time.
- Nozzles in the bodies of the pockets flush cutting and debris away from the milling knives, improving penetration rates and extending the life of the knives.
- Optimized nozzle design allows higher flow rates, using Weatherford's HydraPro™ hydraulics software, to achieve the most productive flow pattern and hole-cleaning capabilities during milling.
- Flow indicator provides positive indication of cutout, preventing "skimming" the ID of the casing.
- Milling knives are dressed with CustomCut™ inserts to provide extended milling footage with maximum penetration rates

Specifications

Eliminator Section Mill

Mill			Casing		Connections	
Body OD (in./mm)	Overall Length (in./m)	Approximate Shipping Weight (lb/kg)	OD (in.)	Weight (lb/ft)	Top Pin	Bottom Box
4-3/8	59.5	230	5-1/2	14 to 23	2 7/8-in. Reg	
111.1	1.5	104				

Section Milling Operations



Reverse-Flow Section Mill

Weatherford's reverse-flow section mill is a hydraulically actuated tool used to mill a section in casing or tubing. This section mill is simple in design, easy to operate, and, with Weatherford's MillSmartSM technology, has acquired an outstanding reputation for milling performance. The milling knives are dressed with Weatherford's CustomCut™ tungsten carbide inserts to provide extended footage with maximum penetration rates.

The section mill is run in conjunction with a taper mill, which has an integral carbide nozzle threaded in the bottom end. Combined with the internal pack-off system, this configuration allows positive fluid control to the section mill knives. Positive fluid control creates a continuous flushing and cleaning action on the knives of the section mill and prevents the cuttings from balling around them. Positive fluid control also keeps the cutting structure cool, which helps to prolong the life of the knives and produces smaller, more controllable cuttings.

Applications

- Milling of a section of casing
 - above and below storage formations
 - in perforated zones in oil wells
 - to squeeze cement to plug old wells
 - to permit a sidetracking operation
 - to allow cement-bonding between new, smaller casing and the formation
- Milling of internal casing patches, screens, liners, and liner packers
- Single-string casing cutting operations

Features, Advantages and Benefits

- Positive fluid control keeps the cutting structure cool and creates a continuous flushing and cleaning action on the knives, increasing the life of the equipment and conserving costs.
- Milling knives are dressed with Weatherford's CustomCut inserts for longer life and cost savings.
- Flow indicator provides a positive indication of cutout, which eliminates skimming the inside of the pipe and ensures proper operation of the tool.
- Various nozzle sizes can be predetermined, using Weatherford's HydraPro™ hydraulics software, to achieve the most productive flow pattern and hole-cleaning capabilities while milling.



Section Milling Operations

API Casing and Section Mill Correlation

Casing					Section Mill			
Casing Size (in./mm)	Coupling OD (in./mm)	Weight with Coupling (lb/ft)	Casing ID (in./mm)	Drift ID (in./mm)	Body OD (in./mm)	Knife Collapse Diameter (in./mm)	Knife Maximum Open Diameter (in./mm)	Dressed Stop Stabilizer (in./mm)
7 177.8	7.656 194.5	17.0	6.538 166.06	6.413 162.9	5-1/2 139.7	6-1/4 158.7	9-1/16 230.2	6-3/8 169.9
		20.0	6.456 163.98	6.331 160.8		6-1/8 155.6	8-15/16 227.0	6-1/4 158.7
		23.0	6.366 161.70	6.241 158.5		6 152.4	8-13/16 223.8	6-1/8 155.6
		26.0	6.276 159.41	6.151 156.2		5-7/8 149.2	8-11/16 220.7	6 152.4
		29.0	6.184 157.07	6.059 153.9		5-3/4 146.0	8-9/16 217.5	5-7/8 149.2
		32.0	6.094 154.79	5.969 177.0		5-5/8 142.9	8-7/16 214.3	5-3/4 146.0
		35.0	6.004 152.50	5.879 174.7		6-7/8 174.6	9-11/16 246.0	7 177.8
		38.0	5.920 150.37	5.795 172.6		6-3/4 171.4	9-9/16 242.9	6-7/8 174.6
7-5/8 193.7	8.500 215.9	20.0	7.125 180.97	7.000 177.8	6-1/8 155.6	6-5/8 168.2	9-7/16 239.7	6-3/4 171.4
		24.0	7.025 178.43	6.900 175.2		6-1/2 165.1	9-5/16 236.5	6-5/8 168.2
		26.4	6.969 177.01	6.844 173.8		6-3/8 161.9	9-3/16 233.3	6-1/2 165.1
		29.7	6.875 174.62	6.750 171.4		8-3/4 222.2	12-5/8 320.7	8-7/8 225.4
		33.7	6.765 171.83	6.640 168.6		8-5/8 219.1	12-7/16 315.9	8-3/4 222.2
		39.0	6.625 168.27	6.500 165.1		8-1/2 215.9	12-5/16 312.7	8-5/8 219.1
9-5/8 244.5	10.625 260.7	29.3	9.063 230.20	8.907 226.2	8-1/4 209.5	8-3/8 212.7	12-3/16 309.6	8-1/2 215.9
		32.3	9.001 228.62	8.845 224.7		8-1/4 209.5	12-1/16 306.4	8-3/8 212.7
		36.0	8.921 226.59	8.765 222		12-3/8 314.3	17-11/16 449.2	12-1/2 317.5
		40.0	8.835 224.41	8.679 220.4		12-1/4 311.1	17-9/16 446.1	12-3/8 314.3
		43.5	8.755 222.38	8.599 218.4		12-1/8 308.0	17-7/16 442.9	12-1/4 311.1
		47.0	8.681 220.50	8.525 216.5		12 304.8	17-5/16 439.7	12-1/8 308.0
		53.5	8.535 216.79	8.379 212.8				
13-3/8 339.7	14.375 365.1	48.0	12.715 322.96	12.559 319.0	11-1/2 292.0			
		54.5	12.615 320.42	12.459 316.4				
		61.0	12.515 317.88	12.359 313.9				
		68.0	12.415 315.34	12.259 311.4				
		72.0	12.347 313.61	12.191 309.6				

Section Milling Operations

Specifications

Reverse-Flow Section Mill

Section Mill Body OD (in./mm)	Casing Sizes (in.)	Overall Length (in./m)	Top Pin Connection*	Approximate Shipping Weight (lb/kg)
5-1/2 139.7	6-5/8 and 7	74 1.88	3 1/2-in. Reg.	450 204.1
6-1/8 155.6	7-5/8		4 1/2-in. Reg.	568 257.6
8-1/4 209.5	9-5/8	87 2.21	6 5/8-in. Reg.	1,050 476.0
11-1/2 292.0	13-3/8	90 2.29	7 5/8-in. Reg.	1,725 782.4

* API regular pin connections are standard; other connections are available on request.

Cut-Out and Milling Ranges for the Reverse-Flow Section Mill

Section Mill Body OD (in./mm)	Range Required During Cut-Out Using 10-PPG Fluid (GPM/LPM)	Range Required During Milling Using 10-PPG Fluid (GPM/LPM)
5-1/2 139.7	100 to 135 378.5 to 511.0	200 to 350 757.1 to 1,324.9
6-1/8 155.6	130 to 150 492.1 to 567.8	500 to 700 1,892.7 to 2,649.8
8-1/4 209.5		
11-1/2 292.0	600 to 700 2,271.2 to 2,649.8	1,000 to 1,100 3,785.4 to 4,164.0



Section Milling Operations

Slimco Section Mill

Weatherford's Slimco section mill is a hydraulically activated tool designed for section milling operations within small-diameter casing. The mill is simple and robust in design, is easy to operate and maintain and has an outstanding reputation for performance. Milling knives are dressed with Weatherford's CustomCut™ tungsten carbide inserts to provide extended footage with maximum penetration rates.

The Slimco section mill has an integral flow indicator, which gives a positive pressure drop at surface when the cutout is made, preventing "skimming" of the casing ID. Nozzles in the body pockets create a continuous flushing-and-cleaning action on the knives of the mill, preventing cuttings from balling around them. This feature also keeps the cutting structure cool, which helps to prolong the life of the knives and produces smaller, more controllable cuttings.

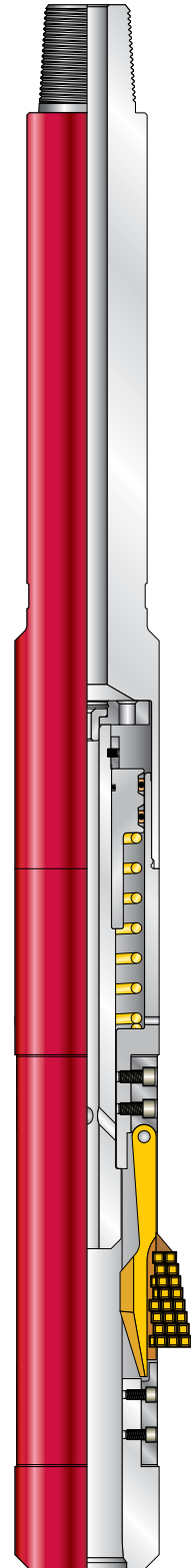
Weatherford's Slimco section mill is a product of the company's MillSmartSM technology—an engineered approach to milling that encompasses a wide range of proven products, services, and technical resources, developed and refined by the world's largest and most experienced provider of milling and fishing services

Applications

- Milling of a section of casing
 - above and below storage formations
 - in perforated zones
 - for squeezing cement to plug old wells
 - to permit a sidetracking operation
 - to allow cement-bonding between new, smaller casing and the formation
- Milling internal casing patches, screens, liners, and liner packers
- Cutting a single string of casing

Features, Advantages and Benefits

- Positive fluid control keeps the cutting structure cool and creates a continuous flushing-and-cleaning action on the knives, increasing the life of the equipment and thus conserving costs.
- Milling knives are dressed with CustomCut inserts for longer life and the resulting cost savings.
- Flow indicator provides a positive indication of cutout, which eliminates "skimming" the inside of the pipe and ensures proper operation of the tool.
- Various nozzle sizes can be predetermined, using Weatherford's HydraPro™ hydraulics software, to achieve the most efficient flow pattern and hole-cleaning capabilities while milling.



Section Milling Operations

Specifications

Slimco™ Section Mill

Mill		Casing OD (in.)
Body OD (in./mm)	Top Pin Connection	
3-3/4 95.3	2-3/8-in. Reg	4-1/2
4 101.6		5
4-1/2 114.3	2-7/8i-n. Reg	5-1/2



Rotary-Shoe Washover Operations

Rotary-Shoe Washover Operations

Rotary shoes (also known as washover shoes) are used in the demanding jobs of milling away formation or tool obstructions, such as stabilizer blades, reamer cutters, expanded packers, and bit bodies, that can hold the drillstring in the hole. Using joints of wash pipe, the rotary shoe can be worked over the string and lowered to the stuck point.

Use rotary shoes to free and wash over:

- Back-off tools
- Drill dollars
- Drillpipe
- Jars
- Keyseat cutters
- Packers
- Reamers
- Rock bits
- Stabilizers
- Subs
- Tubing
- Wireline and cable

Rotary shoes can also be used to mill fishing necks to a sufficient annular clearance so that an overshot can be run for fish recovery. Designs are available for heavy- and thin-walled shoes, for openhole and cased-hole applications.

General Recommendations

During running of rotary shoes, the ROP can be high, causing difficulties with cuttings removal. Pay attention to correct mud conditioning. Ensure that cuttings are removed as milled. If you encounter difficulties achieving the optimal cutting returns, decrease the rotary table speed and the weight on the tool.

Because of the high temperature required for crushed tungsten carbide and CustomCut™ tungsten carbide insert applications, maintain a minimum 3/8-in. wall thickness in the dressed area of the shoe. This thickness eliminates the possibility of steel cracking; it is also critical because of the area needed for effective carbide coverage.

For correct circulation and reduced torque, provide adequate clearance to the ID and OD of the shoe. Weatherford recommends that the ID of the dressed shoe be at least 1/16 in. less than the wash-pipe ID. The clearance enables the shoe to mill the outside of the fish so that it passes into the pipe without interference. Dress the OD of the shoe at least 1/16 in. larger than the pipe OD. The outer dressing of the shoe provides a circulation annulus for cuttings removal. If conditions allow and if the minimum 3/8-in. wall thickness of the shoe is maintained, the clearances are enlarged.

Procedure

1. Back off the stuck string 30 to 60 ft (9 to 18 m) above the stuck point of the pipe to enable running a minimum number of wash-pipe joints. This measure is especially important in an unstable formation. The back-off also frees pipe above the stuck point so that working the wash pipe over the fish is easier.
2. Begin milling at 50 to 100 RPM, and gradually increase to 125 to 150 RPM. Slowly increase the weight from 2,000 to 6,000 lb (907 to 2,722 kg). Light weight and low speed reduce the likelihood of splitting or flaring the shoe. If torque is encountered, reduce the speed and the weight.

Rotary-Shoe Washover Operations

Rotary Shoes

Weatherford's durable, high-performance rotary shoes are dressed with specially selected crushed tungsten carbide or CustomCut™ tungsten carbide inserts to provide continuous sharp cutting edges for long washover intervals.

The tooth rotary shoe is best suited for cutting formation and cement when minimal metal obstructions are encountered in the washover interval. The tool is effective for washing over stuck collars or drillpipe and tubing sanded in place.

The scalloped-bottom (wavy bottom), flat-bottom, drag-tooth, and cripple-tooth designs of rotary shoes enable the shoe wall to be dressed with either of Weatherford's MillSmartSM technologies—crushed tungsten carbide or CustomCut tungsten carbide inserts. With the use of inserts, the ID, the OD, and the entire face of the shoe self-sharpen. Each design eliminates the common difficulty of the carbide face wearing off, exposing a steel ring where the carbide is most needed.

Ordering Information

Weatherford applies dressing anywhere on the rotary shoes—bottom, inside, outside—and in any combination necessary. Depending on the job, wear pads can be provided on the OD to protect the casing. To ensure delivery of the proper rotary shoes for your application, include the following information:

- Type of head design (scalloped, flat, dragtooth, cripple tooth, or tooth)
- Wash pipe size and weight
- Dressed OD
- Dressed ID
- Smooth or rough OD
- Connection size and type



Rotary-Shoe Washover Operations

Rotary Shoes

Weatherford's rotary shoes are used to wash over tubulars that have become sand stuck, mud stuck, or mechanically stuck and for milling over packers, retainers, and bridge plugs. Made of specially tempered steel and dressed with Weatherford's CustomCut™ tungsten carbide inserts and/or crushed tungsten carbide, rotary shoes provide the ultimate in strength, durability, cutting speed, and penetration rate. Rotary shoes are usually run on the bottom of one or more joints of washover pipe to cut clearance between the fish and the wall of the wellbore. Rotary shoe head designs are available in rough OD, for working in openhole wellbores, or smooth OD, for working in cased-hole wellbores. Rotary shoes can be ordered for any length, OD, and ID to meet job-specific requirements, and all come with Weatherford's MillSmartSM technology.

Applications

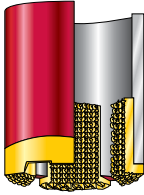
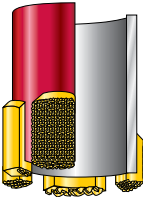
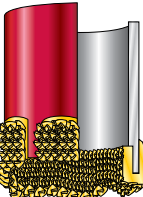
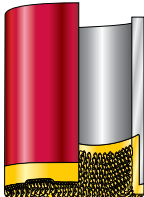
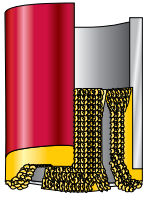
- Milling over blades from stabilizers, cutters from roller-type reamers, and cones from bits
- Washing over sand-stuck, mud-stuck, or mechanically stuck tubulars
- Milling over packers, retainers, and bridge plugs

Features, Advantages and Benefits

- Rugged construction provides optimal strength and durability for long equipment life.
- Smooth OD for cased-hole wellbores reduces risk of casing damage.
- Rough OD for openhole wellbores cuts clearance between the fish and the wall of the wellbore.
- Size range from 3 1/2- to 16-in. OD and shoe head style customization capability for milling on the bottom, on the OD, on the ID, or any combination of the three provide versatility for a variety of applications.
- Increased cutting speed and milling efficiency offer both cost and time savings.

Rotary-Shoe Washover Operations

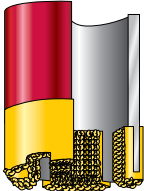
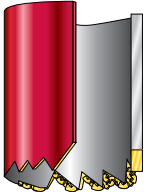
Rotary Shoe Selection Guide

Type A	Type B	Type C
 Used in open hole and inside casing. Dragtooth type shoe for soft formations or when running a weak work string. It cuts on the bottom of the shoe only.	 Used inside casing to wash over and cut on the bottom only. Because this type shoe does not cut on the ID or the OD of the shoe, it will not damage the casing. It cuts on the bottom of the shoe only.	 Used inside casing for cutting metal on a fish without damaging the casing. Does not cut on the OD of the shoe. It cuts on the bottom and the ID of the shoe.
Type D	Type E	Type F
 Used in open hole for washing over and cutting metal and cement with limited inside clearance. Does not cut on the ID of the shoe. It cuts on the bottom and the OD of the shoe.	 Used in open hole for washing over and cutting metal, formation or cement. It cuts on the bottom, the ID and the OD of the shoe.	 Used inside casing to cut metal on a fish. Because this type shoe does not cut on the OD of the shoe, it will not damage the casing. It cuts on the bottom and the ID of the shoe.
Type G	Type H	Type I
 Used in open hole with limited outside clearance, for washing over a fish and cutting metal and a limited amount of cement. Because this type shoe does not cut on the ID of the shoe, it will not damage the fish. It cuts on the bottom and the OD of the shoe.	 Used for sizing and dressing off the top of a fish inside casing. Makes a tapered cut on the fish without damaging the casing. Does not cut on the OD of the shoe. It cuts on the bottom and the ID of the shoe.	 Used in open hole for washing over and cutting the formation, metal, or cement with limited inside clearance. It cuts on the bottom, the ID and the OD of the shoe.



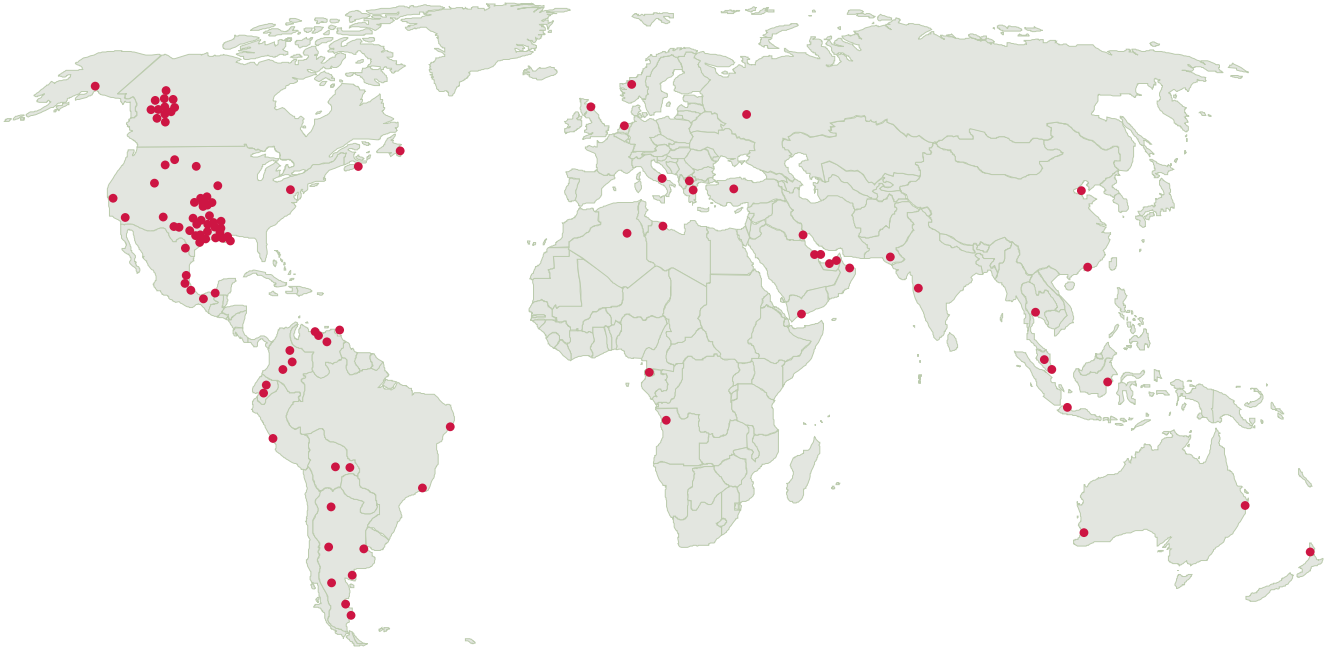
Rotary-Shoe Washover Operations

Rotary Shoe Selection Guide (continued)

Type J	Type K
 Used inside casing for cutting metal on the fish. Because this type shoe does not cut on the OD of the shoe, it does not damage the casing. It cuts on the bottom and the ID of the shoe.	 Used in open hole for washing over and cutting formation only. Does not cut on the ID of the shoe. It cuts on the bottom and the OD of the shoe.
Type L	Type M
 Used in open hole or inside casing for washing over and/or cutting formation only. Does not cut on the OD or the ID of the shoe. It cuts on the bottom of the shoe only.	 Used inside casing for washing over and cutting on the bottom only. Does not cut on the OD or the ID of the shoe. It cuts on the bottom of the shoe only.



Guidelines for Effective Milling



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